Magnetic polarons in low-dimensional semiconductors

A Movsheva[1], Q Gao[1], G Berruto[1], C Hu[5], KD Nguyen[1], H Lin[1], B Goh[3], BG Jang[4], X Xu[5], J-H Chu[5], K Hao[1], R Shreiner[1], A Kindseth[1], AA High[1], S. Yang [1], PB Littlewood [1,2*]

[1] University of Chicago, [2] University of St Andrews, [3]Seoul National University, [4]Kyung Hee University, [5]University of Washington

*littlewood@uchicago.edu

Magnetic polarons often arise when there are exchange interactions between quasi-localised moments and a dilute system of itinerant carriers. The itinerant electrons minimize their kinetic energy by maximizing the bandwidth – facilitated by aligning the local moments. This is a version of RKKY, but has various other monikers in particular systems, including: kinetic exchange in dilute magnetic semiconductors; double exchange in transition metal oxides such as manganites; and Nagaoka ferromagnetism in lightly doped Mott insulators. The carriers may be induced by doping (so are often bound to defects), by optical excitation across the insulating gap (usually an exciton), or by gating.

After a quick review of the history, I will discuss three systems:

1. Transition metal dichalcogenides, where with increased carrier density an optically excited exciton tends to bind to the opposite spin-valley carriers leading to an attractive polaron that is spontaneously magnetic. This may provide an explanation for the magnetic amplification of the Kerr effect [1]
2. The appearance of interaction - driven flat bands in the van der Waals magnet Fe_5GeTe_2, switchable by optical excitations [2]
3. Possible unusual magnetically ordered phases in TMD's doped into the Wigner crystal regime.

References

[1] K Hao, R Shreiner, A Kindseth, AA High, 2022, Science Advances 8 (39), eabq7650
[2] Q Gao, G Berruto, C Hu, KD Nguyen, H Lin, B Goh, BG Jang, X Xu, PBLittlewood, J-H Chu, S Yang1, 2025